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Non Destructive Multi Elemental Analysis Using Prompt Gamma Neutron Activation Analysis Techniques: Preliminary Results for Concrete Sample

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Abstract. In this study, principle of prompt gamma neutron activation analysis has been used as a technique to determine the elements in the sample. The system consists of collimated isotopic neutron source, Cf-252 with HPGe detector and Multichannel Analysis (MCA). Concrete with size of 10x10x10 cm^3 and 15x15x15 cm^3 were analysed as sample. When neutrons enter and interact with elements in the concrete, the neutron capture reaction will occur and produce characteristic prompt gamma ray of the elements. The preliminary result of this study demonstrate the major element in the concrete was determined such as Si, Mg, Ca, Al, Fe and H as well as others element, such as Cl by analysis the gamma ray lines respectively. The results obtained were compared with NAA and XRF techniques as a part of reference and validation. The potential and the capability of neutron induced prompt gamma as tool for multi elemental analysis qualitatively to identify the elements present in the concrete sample discussed.

Keywords: Neutron Induced Prompt Gamma, PGNAA, Isotopic Neutron, and Elemental Analysis.

INTRODUCTION

The Neutron Induced Prompt Gamma Analysis Technique which is well-known Prompt Gamma Neutron Activation Analysis (PGNAA) is emerging as an alternative technique to determine the content of quantitative and qualitative elements in various types of samples [1,10]. It is become more important in industry analysis over years as a non-destructive technique. In general, this technique is based on the measurement of gamma rays emitted following neutron capture reactions by the elements present in the sample detected. The emitted gamma-ray energies characterize these elements and the intensity is proportional to their concentration [9]. Therefore, the gamma-ray spectrum of the sample can give us information content of the elements quantitatively and qualitatively that present in the sample. That means this technique is very useful to identify material characterization, especially to control the quality and originality of the product or material.

The experimental facility assembles based on the isotopic neutron sources, Cf-252 with 4.9μg activity which is used to irradiate the concrete. Wax and other hydrogenous material used to collimate the neutron beam and safety protection purpose. This experimental set-up was designed to develop in-situ non destructive multi elemental analysis in various type of samples such as inhomogeneous sample.

The preliminary result demonstrate the major element in the concrete was determined such as Silicon, Sulphur, Calcium, Aluminium, Iron, Potassium and Hydrogen as well as others elements, such as Chlorine and Sodium by analyze the energy of gamma ray lines respectively. The results of the study presented, indicated the potential and the capability of the Neutron Induced Prompt Gamma Techniques can be developed with low cost, in-situ measurement and non destructive techniques for elemental analysis in the material.

METHODOLOGY

Generally the Prompt Gamma Neutron Activation Analysis (PGNAA) consists of semiconductor detector HPGe, isotopic neutron source and multichannel analyser system. FIGURE 1, shows a schematic diagram of PGNAA experimental system. The position of HPGe detector and collimated neutron source is close to the concrete sample at

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an angle 90° with respect to the neutron beam direction. The isotopic neutron source with 4.9µg activity was used to irradiate the concrete sample.!!

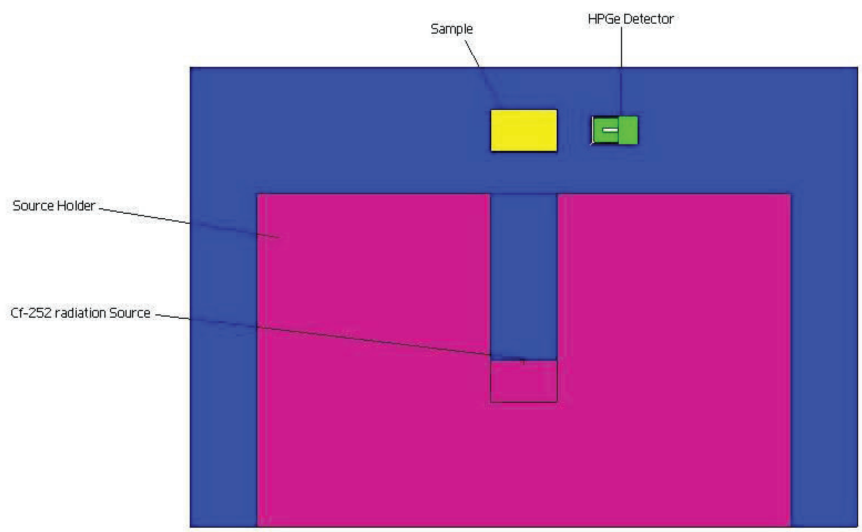

FIGURE 1. Basic schematic diagram of PGNAA experimental system from MCNP geometry Code.

A High Purity Germanium (HPGe) coaxial detector with 43% relative efficiency at 1.33MeV, Co-60 was used to measure prompt gamma rays emitted from the irradiated sample [6]. Materials layer such lead, paraffin and aluminium has been placed surrounding the detector to minimize unwanted radiation entering the detector as well as to protect the detector from damages. The Multi-channel analyzer (MCA) calibrated in the energy region of 0.1 MeV and 15 MeV using the radionuclide Co-60 and C-137 as the reference energy. The elemental photo peak is determined by analyzing the prompt gamma ray spectrum using Multi Channel Analyser software, gammavision 32 [7].

The Basic principle of Prompt gamma activation analysis techniques is illustrated in FIGURE 2 [1]. When neutron emitted by a neutron source (i.e. ^{252}Cf) enter a medium of target, depending on the type of material, neutrons can pass through with long distance before interacting with nucleus. Neutrons can interact with nuclei of materials in two ways to yield characteristic prompt gamma-ray emission. First, fast neutron (> 1 MeV) can scatter in-elastically from a nucleus, losing energy in the process and exciting the nucleus to a higher energy state. Immediate de-excitation of the nucleus produces a gamma-ray characteristic of the excited nucleus. Second, neutrons with energy around the thermal value (0.025 eV) can be captured by a nucleus. A compound nucleus is formed in an excited state and the prompt de-excitation of this capture nucleus causes the emission of a characteristic capture gamma-ray. The presence of a gamma-ray line with a particular energy is used for qualitative analysis. In addition, the intensity of the line is used for quantitative analysis. The range of gamma-ray in a typical bulk medium is approximately 20 to 25 cm [3].

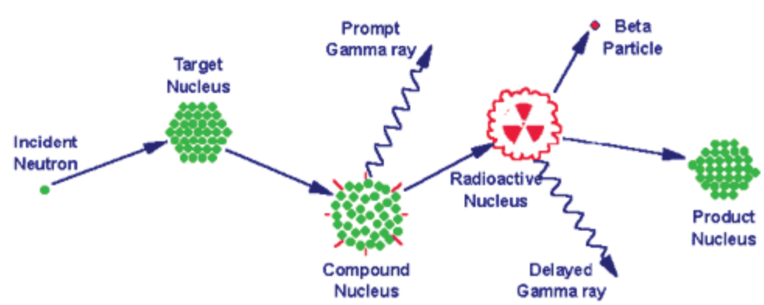

FIGURE 2. Diagram illusion the process of neutron capture by target nucleus followed by the emission of prompt gamma ray, delayed gamma and beta particle.

Normal standard of concrete prepared as sample in this study. Material composition ratio of Portland cement, fine aggregate, coarse aggregate include water per kilogram as a shown in TABLE (1). The samples in cubical shaped with dimension 15cm x 15cm x 15cm and 10cm x 10cm x 10cm respectively.

TABLE (1). Basic material composition ratio of the concrete sample [4].

Material	**Wt(%)**
Portland cement	13.24
Fine aggregate (sand)	26.49
Coarse aggregate	52.98
Fresh water	7.28

RESULT AND DISCUSSION

The FIGUREs 3 and 4 show the prompt gamma ray spectrum of the CB and CK concrete sample respectively using HPGe detector with 43% relatively efficiency at 1.33MeV, Co-60 and the irradiation time is 6 hours. Both of spectrums shown various elements in gamma-ray line respectively such as Silicon (Si) 4.93MeV and 3.54 MeV, Calcium (Ca) 4.42MeV and 6.42MeV, Chlorine (Cl) 6.11MeV and 6.62MeV, Sodium (Na) 6.39MeV and Hydrogen (H) 2.22MeV. The others element been detected are Aluminium (Al) 7.72MeV, Iron (Fe) 7.6MeV, Potassium (K) 5.38MeV and sulphur (S) 3.22MeV and 5.42MeV. The two of sample spectrum also showed no significant difference in terms of the count, the intensity and the background. That mean the size of sample in this experiment not give any significant influence.

Since these elements normal and significant component elements of concrete, thus the relative characteristic of gamma-ray energies present in the sample can be used to determine the grade of concrete such as the purity, properties and quality. However, in this experiment the volume of background intensity is high while the elements intensity is quite small. Therefore it’s quite difficult to calculate the quantitative of each element

The TABLEs (2) and (3) shows the results from XRF analysis for both of concrete sample. it's just four element was determined using this techniques such as S, Si, Ca and Fe with percentage of concentration 2.996% & 3.596%, 16.63% & 15.96%, 73.11% & 71.14%, and 6.90% & 7.55% respectively. The higher percentage of concentration of the Ca and Si show that, these two elements were very significant to concrete component. That mean, by analyse this elements can be a key to know the properties of the concrete. The comparisons between the both of sample not provide any difference significant for both elements, Si and Ca.

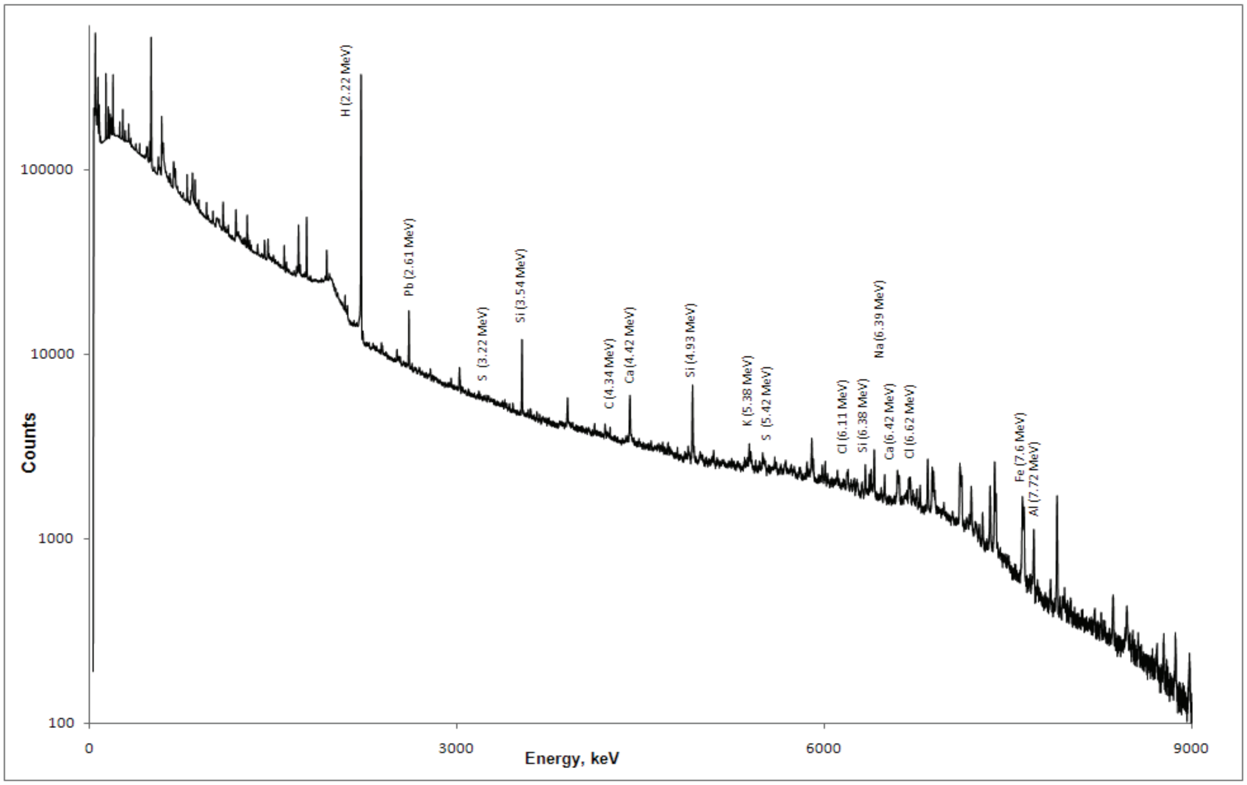

FIGURE 3. Gamma-ray spectrum of concrete sample, CB with energy range 0 – 9 MeV.

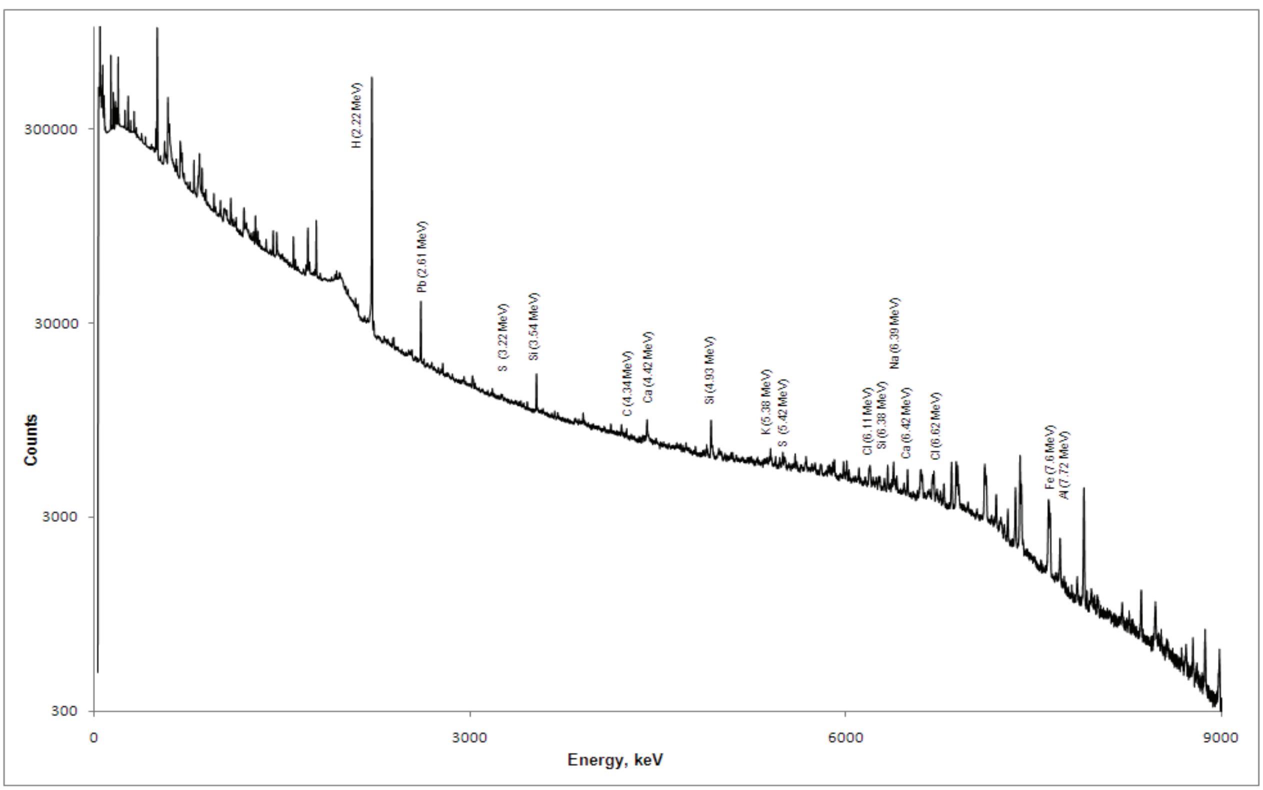

FIGURE 4. Gamma-ray spectrum of concrete sample CK with energy range 0 – 9 MeV.

TABLEs (4) and (5) shows the results form NAA Techniques analysis. Its show various elements related content of concrete was determine such as Mn, Ca, K, Mg, Fe and Na with concentration (mg/kg) respectively. Both of sample results show the Ca is very significant to concrete component but have limitation, no data provided for Si element.

TABLE (2). Identified peak elements related with a content of concrete element (sample CB) from XRF Technique

Nuclide	Concentration	Peak (cps/mA)
Sulphur, S	2.996 %	158
Silicon, Si	16.63 %	182
Calcium, Ca	73.11 %	12048
Iron, Fe	6.900 %	1326

TABLE (3). Identified peak elements related with a content of concrete element (sample CK) from XRF Techniques

Nuclide	Concentration	Peak (cps/mA)
Sulphur, S	3.596 %	185
Silicon, Si	15.96 %	169
Calcium, Ca	71.14 %	11448
Iron, Fe	7.550 %	1416

TABLE (4). Identified peak elements related with a content of concrete element (sample CB) form NAA Technique

Nuclide	Energy	Concentration (mg/kg)	Uncertainty
Manganese, Mn	1811	321	45
Calcium, Ca	3083.00	<700	
Potassium, K	1524.00	2837	68
Magnesium, Mg	1014	2038	100
Iron, Fe	1292	7776	186
Aluminium, Al	1779.00	333.	0.017
Sodium, Na	2754	259	25

TABLE (5). Identified peak elements related with a content of concrete element (sample CK) form NAA Technique

Nuclide	Energy	Concentration (mg/kg)	Uncertainty
Manganese, Mn	1811	704	112
Calcium, Ca	3083.00	89303	4522
Potassium, K	1524.00	9019	510
Magnesium, Mg	1014	3166	126
Iron, Fe	1292	9022	655
Aluminium, Al	1779.00	19076	83
Sodium, Na	2754	1534	107

Generally, the comparison results from PGNAA techniques and two others NAA and XRF techniques show that, the PGNAA techniques can be use to determine almost element in the concrete sample by analyze the gamma-ray line each elements. Knowledge of the ratio of Si/Ca and analysis the peak of energy is considered to be key factor to determine the grade and properties of concrete [5]. Besides that, by determine the chlorine and sodium in the concrete, it also can be used to study on concrete corrosion which is the main problem for the reinforcement concrete [8]. However, it is difficult to analysis the peak energy of elements to know the concentration due to low intensity, higher background and not so god energy resolution. That means, for the next step of research and experiment there are areas which needed improvement and suggested to use a different detector with higher neutrons activities to obtain better peak of energy and intensity of gamma-ray. The experimental setting such as irradiation time, distance between source, detector and sample, type of detector and source activities also have to be optimized as well.

CONCLUSION

Based on this preliminary result, the Prompt Gamma Activation Analysis Techniques can be use for evaluation element content and composition in the sample, such as concrete material in this experiment. This technique is non-destructive with simple sample preparation, in-situ measurement, portable and use very low activity of radioactive. This techniques can be key factor to studies the concrete properties and the corrosion problem in the reinforcement concrete. On the other words, this techniques can be use to evaluate the grade of concrete or other material in the field.

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